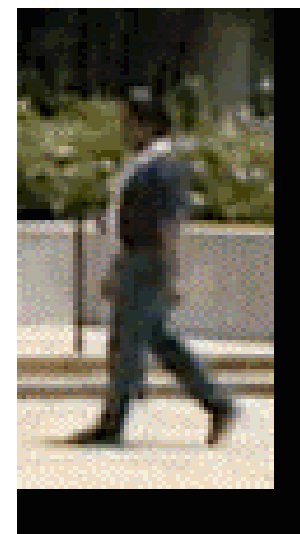


# Outdoor Biometrics over Time by Fusing Gait with Face

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# Outline

- **Challenges for gait and face biometrics**
  - Indoor vs. outdoor
  - Time (months apart or more)
- **Recognition algorithms**
  - Face: elastic bunch graph matching (EBGM)
    - USC, CSU implementation
  - Gait: normalized gait cycle
    - USF
- **Combination**
  - Score sum
  - Bayesian rule
- **Performance analysis**



# Difficulties in Gait and Face Recognition

# Challenges for Face Biometrics

- Based on latest NIST face evaluation report (FRVT 2002)
- At 1% false alarm rate:
  - Indoor with lightening control:  $P_V > 90\%$
  - Indoor Vs. Outdoor:  $P_V < 50\%$



# Challenges for Gait Biometrics

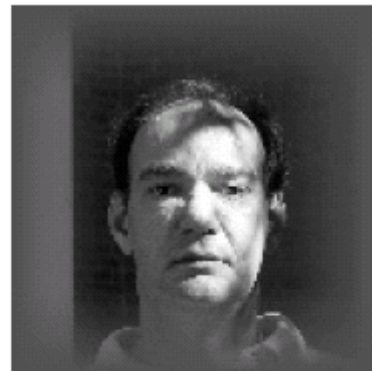
- Based on HumanID Gait Challenge Problems
  - CMU, UMD, MIT, SOTON, CAS, UCR and USF
- At 1% false alarm rate:
  - Sequences taken at same day:  $P_V > 90\%$
  - Sequences taken with 6 months apart:  $P_V < 24\%$



# Recognition Algorithms

# Face Recognition Algorithm (USC)

- Elastic Bunch Graph Matching (EBGM)
  - proposed by Wiskott *et al.*, 1997, USC
  - Based on Gabor features
  - Has superior performance than other template based methods, such as PCA, LDA. (FRVT 2002)
  - Use the CSU implementation

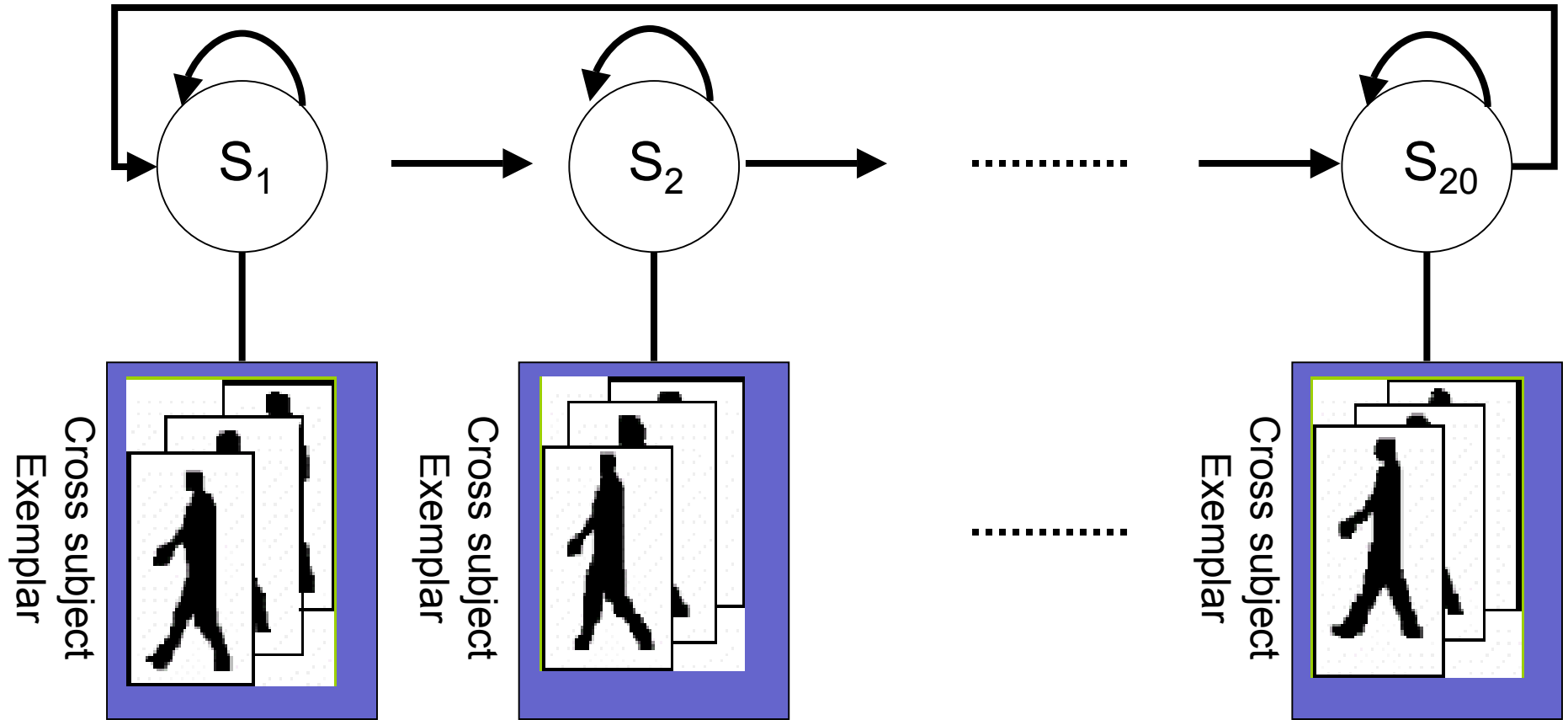


# Gait Recognition Algorithm (USF)

- Shape-based algorithm
- Silhouette detection: background subtraction and EM threshold
- A population Hidden Markov Model to estimate the frame-stance matching
- Choose the Euclidean distance between the mean images of corresponding stances

# Population HMM

Left-right cyclic Bakis Model

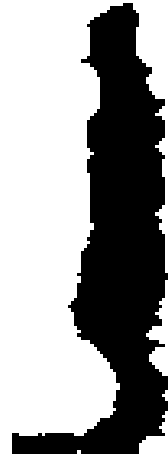


# Forming Averaged Gait Cycle



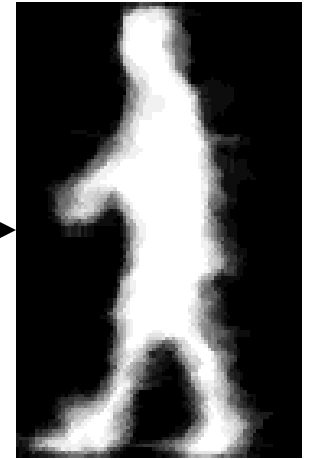
Original frames

Background  
Subtraction



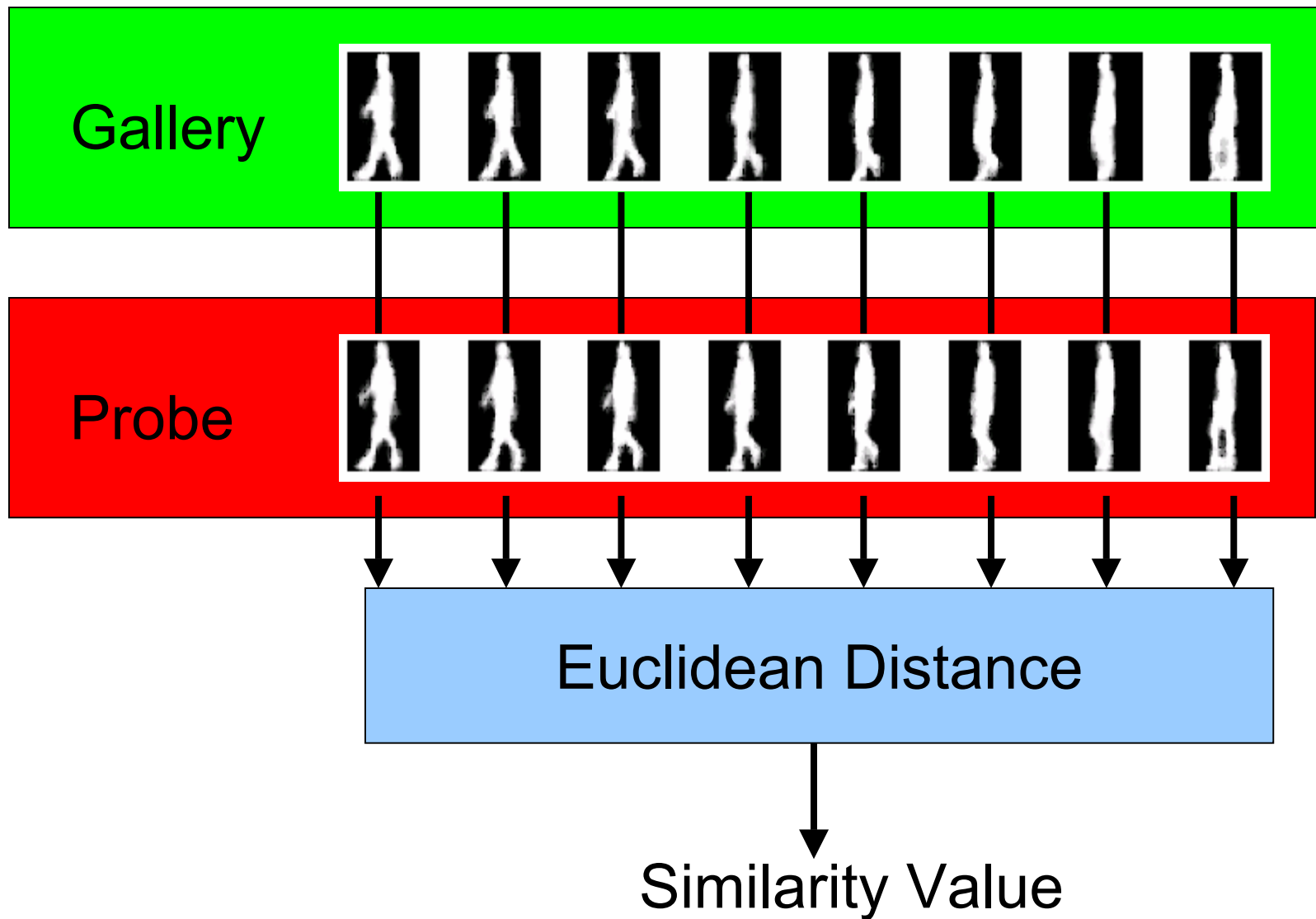
Binary silhouettes

Population  
HMM



Averaged silhouettes

# Similarity Computation



# Combination Schemes

# Combination Introduction

- The feature extraction level
  - Data from each sensor are combined to form one feature vector
- The matching score level
  - Similarity scores computed by individual classifier are fused
    - Sum, product
- The decision level
  - Each classifier makes its own decision and votes for the final decision
    - Rank sum, majority vote

- Score Normalization: Z-Norm

$$\text{NormSim}(p, g_i) = \frac{\text{Sim}(p, g_i) - u_p}{\sigma_p}$$

- Combination:

$$\text{CombSim}(p, g) = \text{NormSim}_{\text{gait}}(p, g) + \text{NormSim}_{\text{face}}(p, g)$$

# Bayesian Rule

- Form 2D score vector

$$V = \begin{bmatrix} S_{face} \\ S_{gait} \end{bmatrix}$$

- Likelihood is modeled as multi-dim Gaussian distribution

$$P(V | m) = \frac{1}{2\pi |\Sigma|^{0.5}} e^{[-0.5(V-u_m)^T |\Sigma|^{-1} (V-u_m)]}$$

- Compute the posterior using Bayesian rule

$$P(m | V) = \frac{P(V | m)P(m)}{P(V)}$$

- Employ the posterior difference as similarity

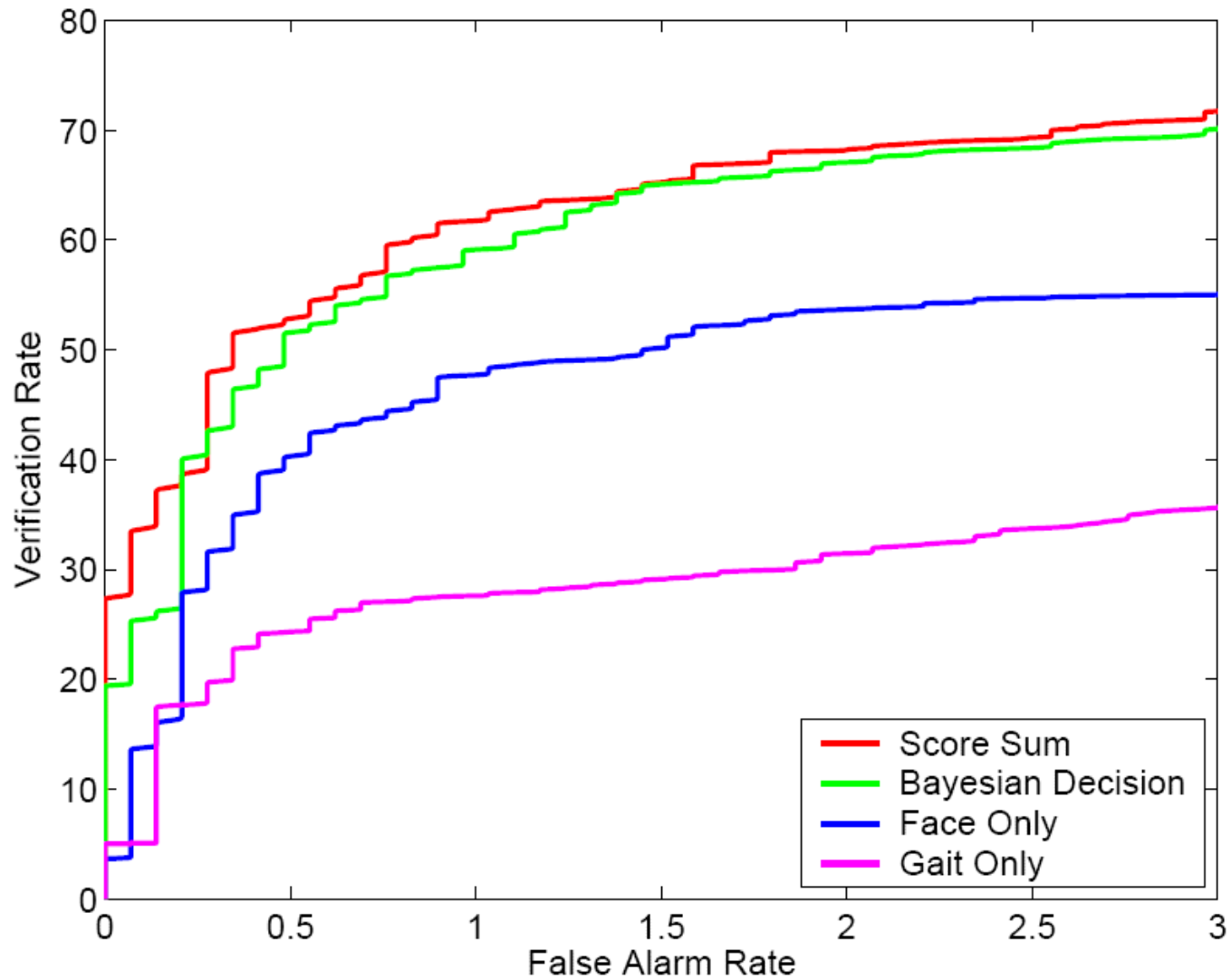
$$CombSim(p, g) = P(m | V) - P(nm | V)$$

# Experiments and Results

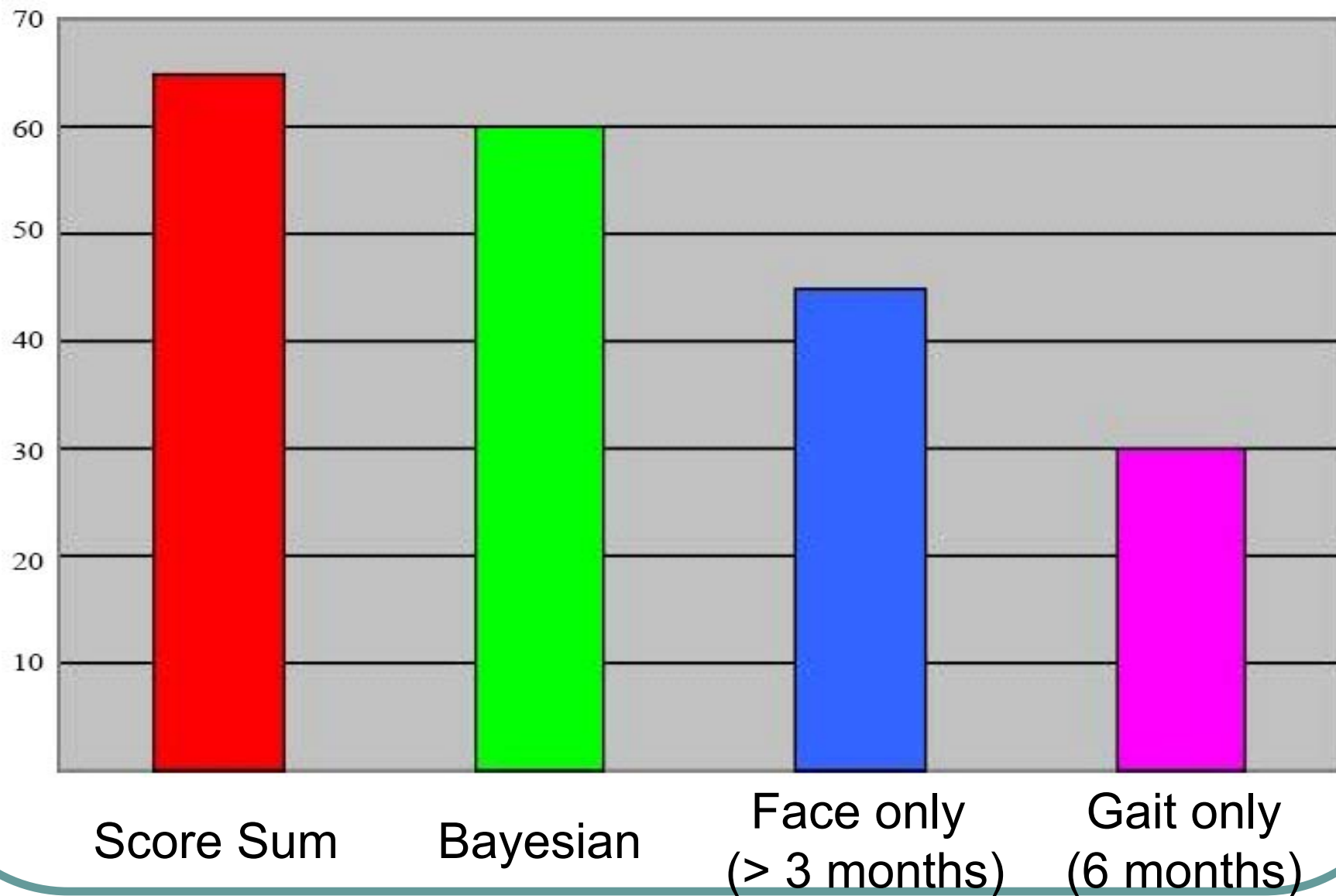
# Experiments

- NIST HumanID dataset
- Gallery set: 71 subjects, May 2001
  - Face: indoor
  - Gait: outdoor, grass field
- Probe set: 21 subjects
  - Face: outdoor,  $\geq 3$  months
  - Gait: outdoor, grass field, 6 months apart
- Difference: indoor-outdoor, time

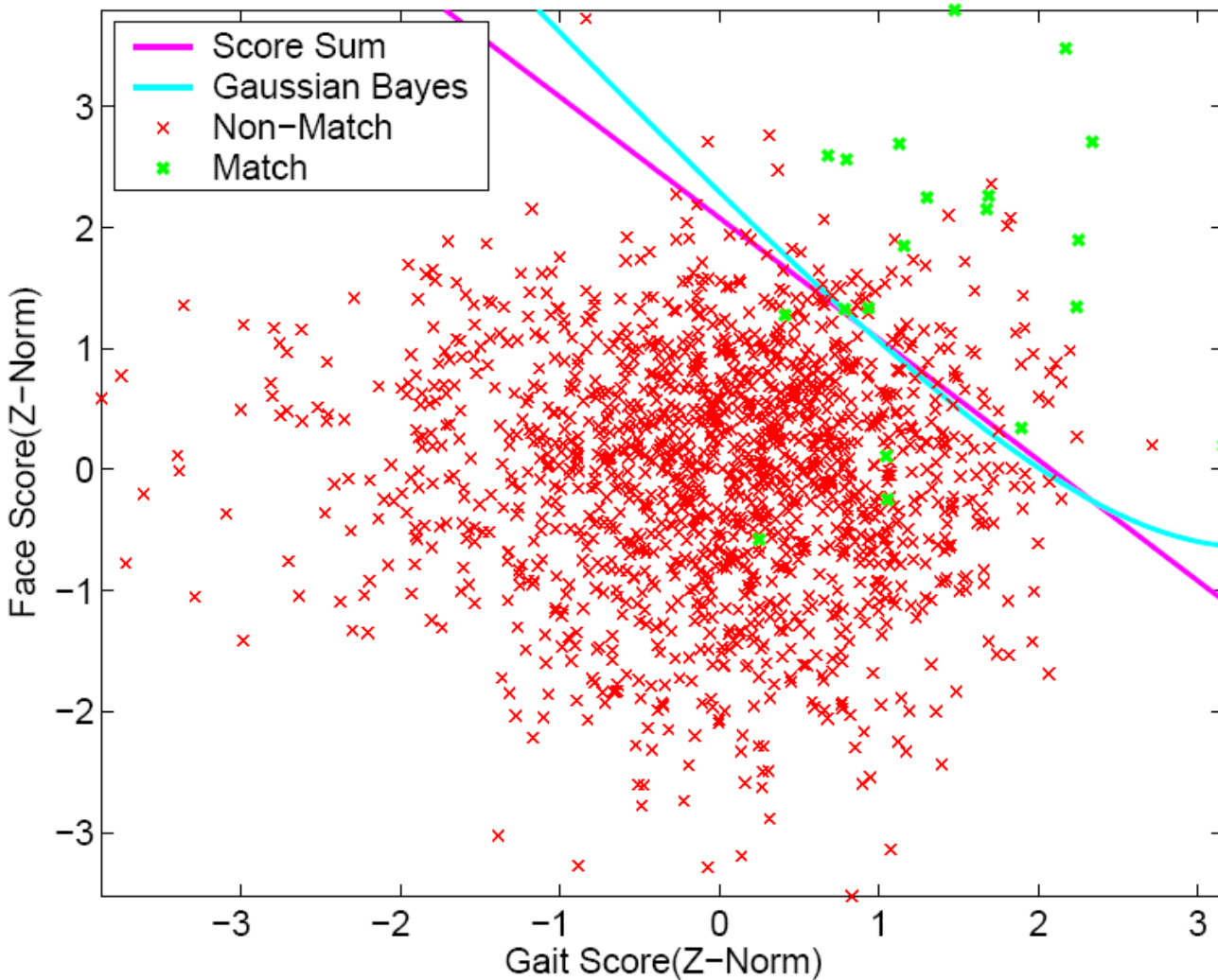
# Result: ROC Curve



# Verification Rate at 1% False Alarm Rate



# Decision Boundary at 5% False Alarm Rate



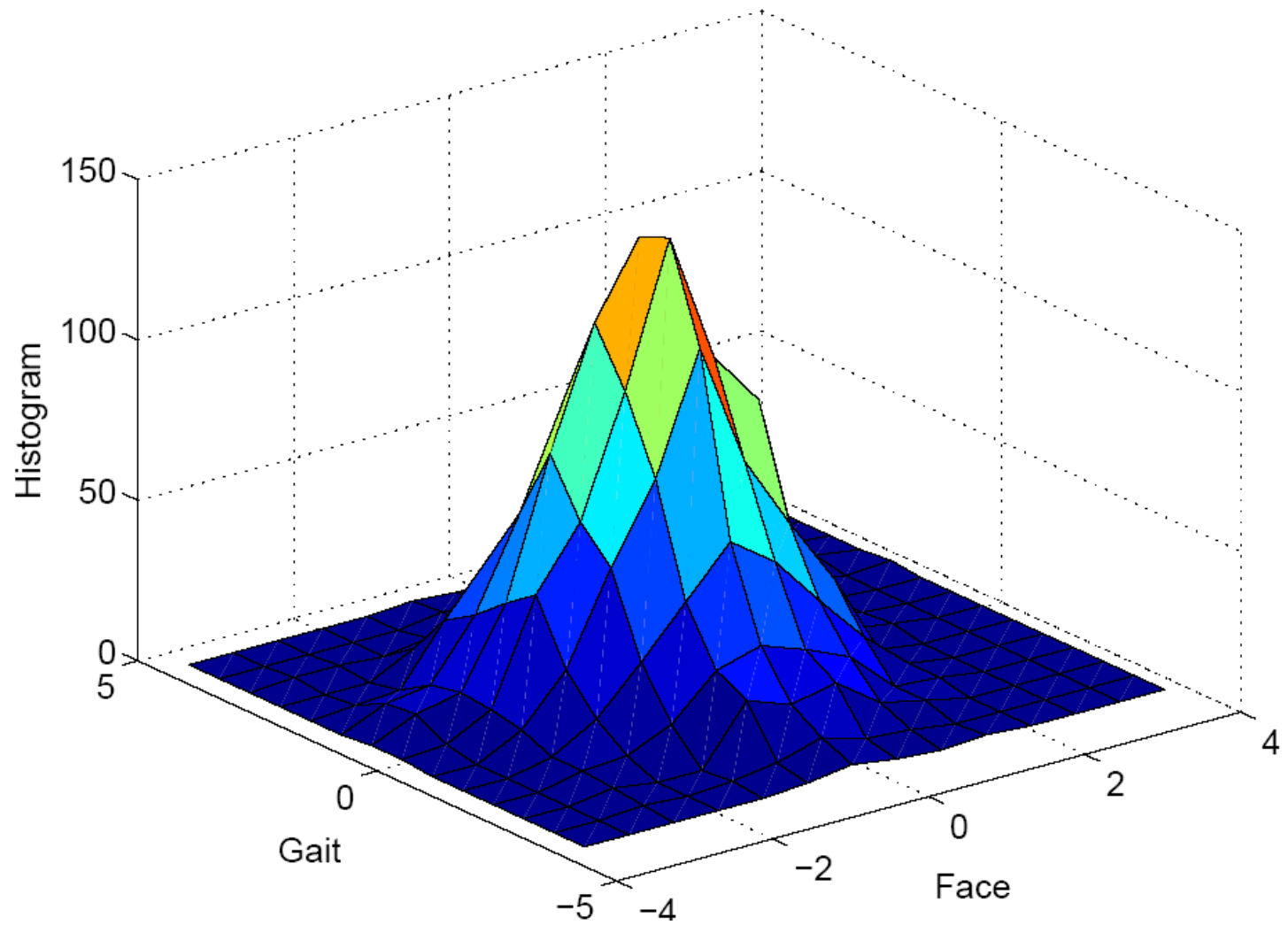
# Conclusions and Summary

- Typical hard problems for face and gait biometrics:
  - Outdoor recognition
  - Time Variation
- Combination Schemes:
  - Score Sum
  - Bayesian Rule
- Performance Evaluation ( $P_V$ ,  $P_F$ )
  - Combination results are much better than individual classifiers (20% increase in  $P_V$ )
  - Score sum is slightly better than Bayesian rule
  - The improvement can be explained by the low correlation between the scores of the two classifiers
- Combination offers an effective solution for improving weak classifiers.

Thank you!

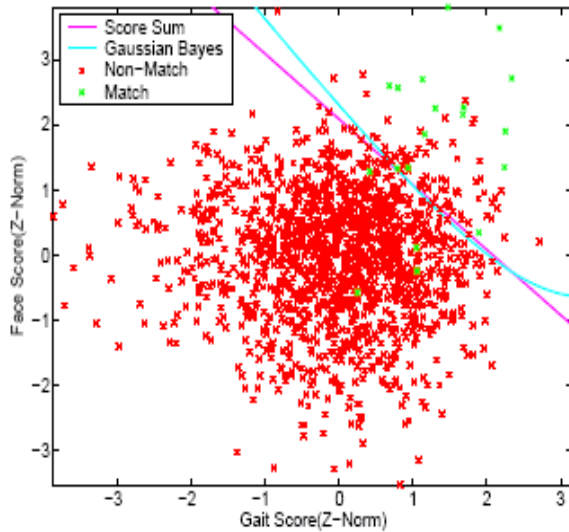
Sep. 20, 2004

# 2D Histogram of non-match Scores

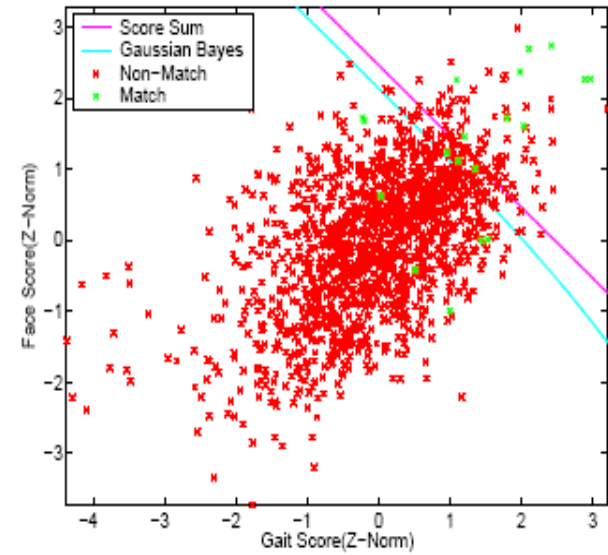


# Decision Boundary at 5% $P_F$

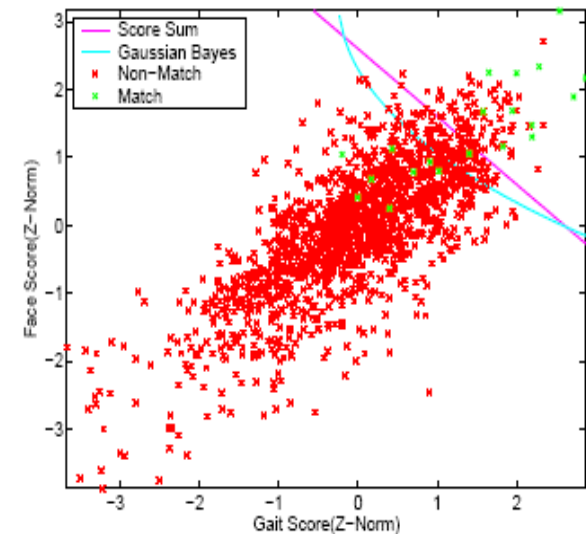
F+G



F+F



G+G



# Comparison of Intra-model and Inter-model combination

